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Review Article

Assessment of Pesticide Use against Tephrtidae Fruit Fly and other Pest Among Small-Scale Solanaceous Vegetable Farmers in Bugorhe-Kabare the Democratic Republic of Congo

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ISSN: 2770-6745

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Submission: February 23, 2022

Published: March 31, 2022

Volume 2 - Issue 2

How to cite this article: Jean ARK*, Jean BMB. Assessment of Pesticide Use against Tephrtidae Fruit Fly and other Pest Among Small-Scale Solanaceous Vegetable Farmers in Bugorhe-Kabare the Democratic Republic of Congo. Biodiversity Online J. 2(2). BOJ. 000533. 2022. DOI: 10.31031/BOJ.2022.02.000533

Abstract

India is a country of diverse cultures due to the influence of geography, climate and biodiversity. The current state of the developing world is the result of this process of evolution and experimentation. As Indian agriculture was later considered to be the backbone of the Indian economy, the contribution of agribusinesses to India's national income increased even more. Science and Technology has always being the tool for advance agricultural practices and India is way ahead in applying the same to rise as a largest economy. FAO recognized the contribution of India as a third largest economy in the world after US and China however also concern about the food shortage and malnutrition. The increasing feminization of agriculture is mainly related to the migration of men from rural to urban areas and other domestic issues. To address the issues, a model is proposed for rural India for integrated agriculture based approach with involvement of every household from a small village to cater the need of food and livelihood thereby also progressing in further development for a better life.

Introduction

Different types of insect pests afflict production in western Albertan Rift area [1,2]. Tephritid fruit flies such as Dacus bivittatus (Bigot), Dacus punctatifrons Karsch, Batrocera dorsalis (Hendel) (syn. B. invadens [Drew, Tsuruta & White]), Bactrocera latifrons (Hendel), Ceratitis cosyra (Walker), Ceratitis rosa Karsch, Ceratitis fasciventris Bezzi, Ceratitis capitate (Wiedemann), Zeugodacus cucurbitae (Coquillett) and other pests such as Helicoverpa zea (Boddie) (Noctuidae), Tuta absoluta (Meyrick) (Gelechiidae), Anarsia lineatella Zeller (Lepidoptera, Gelechiidae), Comstockaspis perniciosus (Comstock) (Hemiptera: Diaspididae) constitute a major constraint to increased production of fruits and vegetables in orchards and gardens [3-7] and those small-scale farmers has a lack of fundamental horticultural knowledge [8]. For example, fruit damage due to the native tephritid fruit fly species was already high, causing serious problems to growers. However, this situation was exacerbated with the invasion of B. dorsalis, with damage frequently reaching 100% in the absence of effective pest management [9,10]. This highly invasive species has since displaced local fruit fly species from smallholder crops [9]. Even today, [11] show that, despite the advances in agricultural sciences, losses due to pests and diseases range from 10 to 90%, with an average of 35-40%, for all potential food and fiber crops. The relative economic impact is perhaps strongest felt by smallholder farming families that count on the small-scale sales of high-value crops significantly to contribute to the family economics. The enormous losses

they cause through direct damage to fruit, vegetables, and loss of market opportunities. Further, competitive release implies the need for a combination of lures and methods. These observations are important for developing control schemes tailored for smallholder settings. Pest management and control strategies should thus be amenable to both large-scale productions and small-scale farming, with emphasis on the latter [12]. Pesticides are agricultural technologies that enable farmers to control pests and weeds and constitute an important input when producing a crop. Promoting sustainability in agricultural production requires critical consideration of agricultural technologies and identification of best practices [13,14]. Several authors [15,16] demonstrated that agro-pesticide technologies, including insecticides, fungicides and herbicides, formed one of the driving forces behind the Green Revolution. In fact, coupled with high-yielding crop varieties and increased land for crop production, significant yield improvements were achieved. However, this was realized at the expense of the natural environment and the health of farmers. The unsafe use of pesticides is common in developing countries is shown in different studies conducted on knowledge, attitude and behavior among smallholders [11, 17]. Tephritid flies attack a large variety of fruits, which constitute highly priced commodities in many countries. Insecticides have been used extensively for their control. Although resistance development in fruit flies has not kept pace with that in other insects, possibly due to their high mobility and tendency for wide spatial dispersal, recent studies have indicated that selection pressure has now reached the point where resistance is detectable in the field and control may therefore become problematic [18]. Moreover, requirement of pesticides in vegetables is comparatively higher than the other food products [19] in Bugorhe area at Kabare, South Kivu province. Bugorhe area is one of the major suppliers of vegetables in the Bukavu town. However, the sharp increase in the urban population of Bukavu town poses several challenges, including food security (supplying these cities with food), job creation and income generation [20, 21]. In order to meet these challenges, poor families in cities resort to market gardening [21,22]. These market garden centers generally exploit fruit vegetables (tomato, chilli, pepper, eggplant, okra, and watermelon), tubers / bulb (carrot, onion) and some exotic leafy vegetables (scallions, leek). Indeed, [10] reported that a lack of IPM research relevant to small farms is perhaps a more serious problem than the provision of advisory services. Again, market garden smallholders have a lot of difficult to get chemical pesticides, traps, lures and food baits, lack of IPM method and IPM experts, lack of knowledge on the use and consequences of chemical pesticides and lack of packaging management. Those market garden smallholders saw and know fruit flies and other pest at solanaceous crop. In addition, the market garden smallholders do not know the good way to use chemical pesticides and traps such as lures as well as food bait are not sold in the east of the DRC in general and in South Kivu in particular. Relatively no research has been conducted on the use of pesticides on market garden such as solanaceous crop in study area. However, this study assesses the pesticides use: farmer's practices, their knowledge and perceptions regarding the uses of chemical pesticides in study area. This paper reports findings on practices and use of pesticides in control of tephritidae flies and other pests by small-scale vegetable farmers in Bugorhe-Kabare area at the western of Albertan Rift area.

Materials and Methods

The study consisted of interviews with farmers and farm workers in rural areas in Bugorhe- Kabare area, where horticultural crops (vegetables, flowers, fruits) were mostly cultivated using farm inputs, particularly pesticides. It was carried out in Bugorhe area, which is located at the Kabare territory (Latitude: 2° 30′ and 2° 50′S, Longitude: 28° 45′ and 28° 55′E, Southwestern of the Kivu Lake) at the South Kivu province, eastern part of DR Congo. It is peripheral to the Kahuzi-Biéga National Park is located in the community Kabare chiefdom in South Kivu Province and inhabited by the Bashi ethnic group [23]. The survey covered the period from January 01 to March 28; 2021.Simple random sampling was used to select the sample from the population. This is the least biased technique and also gives every element an equal chance for selection during the study [24] and some criteria were followed by the quota method [25,26]: being market gardeners (tomato, pepper, eggplant and pepper) and/or sellers of phytosanitary products and in one of the localities of the Bugorhe group, 12 market gardeners of these solanaceous and sellers of phytosanitary products of male and female sexes combined and chosen by locality, the freedom of choice left to the investigator. The sample size is 96 market gardeners. Research instruments include reconnaissance survey, interview questionnaire pre-test, household interview and field survey, smallholder vegetables and focus group discussions. The semi-structured type of questionnaire considering the purposed of study is to assess the pesticides use, farmer's practices, their knowledge and perceptions regarding the uses of pesticides. These include the socio professional characteristic of small-scale solanaceous vegetable farmers, crop production, main market gardeners' crops used, types of pesticides, WHO Hazard Class and health effects (2005), pesticide application, pesticide mixtures used, trend in pesticide use, reasons given for the trends in pesticide use, perception of pesticide poisoning symptoms, system of pesticide packaging management. Data was obtained from primary and secondary sources. However, a questionnaire composed of semi-structured items was designed based on the published literature on the subject as well as the authors' experiences in the field. Data was collected through an agricultural survey through face-to-face interviews with farmers or farm workers during agricultural activities. Indeed, the questionnaire was designed in French and translated into Kiswahili (the national language). The former is understood by the majority of farmers and pre-tested with small samples of farmers in the same areas before using it in this study. The survey data were been encoded in Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, WA, USA) and R software (R Core Team, 2018) were analyzed. Two-way ANOVA was used at the significant level of 1%. The Tukey multiple comparison was been used too at the confidence level of 95%. Before the variance analyze application, normality verification of data distribution hypothesis

was been done by the Bartlett's K-squared test and the descriptive result was expressed by percentage.

Results

a. Socio Professional characteristic: The majority of farmers were male (79.17%) with an average age of 30, ranging from 30 to 60, reported the use of different pesticides in more vegetable farms in Bughore-Kabare zone. According to their level of education, 46.87% of these men attended primary school and 36.46% secondary school and 16% university, while 63.54% of them did not have agricultural training and 36.46% are trained in agriculture

b. Solanaceous output in study area during the period of 2017 to 2021: The mean of tomato (5780kg±471.17) differed to the mean of eggplant (4700kg±158.11). Le table 1 presented the ANOVA summary of solanaceous output in study area during the period of 2017 to 2021. The table shows a significant difference between the outputs of market garden crop (Table 1). In case of years, there is not difference, i.e., during the five years solanaceous products were the same with an high tomato output.

Table 1: ANOVA summary of solanaceous products.

Source of variance	DF	Somme of Square	Square of Mean	F value	Pr(>F)
Years	1	144500	144500	1.199	0.30973
Market garden	1	2916000	2916000	24.199	0.00172 **
Residuals	7	843500	120500		
Tukey multiple comparison					
	Difference	Lower	Upper		P adj
Tomato-eggplant	1080	560.8586	1599 .141		0.0017151

c. Main market gardeners' crops used: The main cultivated solanaceous crops grown in the Bughore area is tomato (Lycopersicon esculantum) at 47.92% followed by eggplant (Solanum melongena) at 36.46%, pepper (Capsicum frutescens) at 10% and pepper (Capsicum annum) at 5.21%. Every farmer has a reason to choose vegetable crops, one for their easy-to-practice short-cycle crops, and another for their short-term profitable investment, and the last for their very high market value crops per unit area.

d. Types of pesticides: Farmers in the Bughore-Kabare region most often use insecticides (44.79%) and fungicides (43.75%) but also 4.17% herbicides and 7.29% rodenticides due to the production of tomatoes, eggplants, peppers and peppers and other vegetables. The type and number of pesticides used in different crops depended on the pest population and their potential damage to the crop as well as farmers' perception of pest management practices (Table 2). Additionally, pesticides were supplied in containers ranging from 0.5 liters to 5 liters or in packs ranging from 0.5 kilograms to 25 kilograms. In most cases, a liter and a kilogram were common, as well as the distribution of small quantities by vendors. The table 1 of types of pesticides used in small-scale vegetable farms in Bughore area classified using the WHO Hazard Class and health effects, 2005. In the Bughore-Kabare area, of the Class II (moderately hazardous), III (slightly hazardous) or U (unlikely to present an acute hazard) insecticides and fungicides registered in use, 20% contained chemicals suspected of being endocrine disruptors, 40% were cholinesterase inhibitors and 35% each were carcinogenic and potentially carcinogenic. Many end-of-use pesticides were not registered for general use. Carbofuran, a nematicide, zinc phosphide, a rodenticide, and methomyl, an insecticide, were the only WHO class Ib (highly hazardous) not used. However, the insecticides used included pyrethroids (such as cypermethrin, deltamethrin, permethrin, acelamectin (abamectin, abactin and acetamiprid) and lamda-cyhalothrin); organophosphates (such as pirimiphos-methyl, profenofos, chlorpyrifos, dichlorvos, fenitrothion), dimethoate and carbamates (carbofuran) and dithiocarbamates (Glucocorticoids). The most popular fungicides were copper-based such as copper oxychloride, copper hydrochloride, and copper sulfate, although metalaxyl-M, zinc, manganese, and mancozeb were also used

Table 2: WHO hazard class and health effects, 2005.

Trade Name	Common Name	WHO Class A	Health Effects B	Target pests	Registration status C
Cobox	Copper oxychloride	III		Fungus	R
Cypercal	Cypermethrin	II	SE, PC	larger-grain-borer	R
Dimethoate	Dimethoate	II		Insects	R
Dithane M45	Mancozeb	U	SE, C	Fruit fly, blight, downy-mildew, leaf-rust, wilting	R
Dursban	Chlorpyrifos	II	CI	Stem-borer, Cutworms, armyworm	R
Dust	Methyl+permethrin	NK	PC	Stem-borer	R

Dynamec	Abamectin	II		insects	R
Funguran	Copper hydoxide	III		Leaf-rust	R
Ivory 80WP	Mancozeb	U	SE, C	Blight	R
Mamba	Glyphosate	U		Weeds	R
Polytrin	Cypermethrin	II		Thrips, insects	R
RedCat	Zinc phosphide	Ib		Rats	U
Ridomil	Mancozeb+metalaxyl	NK	SE, C	Blight, spidermite	R
Rogor	Dimethoate	II		Stalkborer	U
Roundup	Glyphosate	U		Weeds	R
Selecron	Profenofos	II	CI	Whitefly, spidermite, Fruit-borer,stemborer, insects, thrips, aphids	R
Shumba dust	Fenitrothion+deltamethrin	II	CI	Larger-grain-borer	R
Sumithion	Fenitrothion	II	CI	Stem-borer	U
Thiodan	Endosulfan	II	SE	Larger-grain-borer, stem-borer, leafminer,red-ants, beetle	R
Thionex	Endosulfan	II	SE	American-bollworm, aphids, mites, insects, leafminer, stalkborer	R

e. Pesticide application and mixtures used: More than 50% of farmers applied pesticides using knapsack sprayers up to once a week depending on the type of vegetable crop. Twenty-eight point zero four percent of farmers reported two pesticide applications and five times (10.42%) and six times (7.29%) per week, i.e., routine pesticide applications. The majority of farmers applied pesticides once a week. The fact that pesticides are more expensive and use cultural control methods and occasionally botanical pesticides. More farmers surveyed applied mixtures of pesticides. Reported pesticide mixtures included fungicide + insecticide (Dithane M45 and Ascozeb 80WP) reapplied to onions and tomatoes, Maneb and Rocket EC to tomatoes, onions and cabbage. In addition, other pesticide mixtures are two fungicides + insecticide (Dithane M45, Ascozeb 80WP and Ivory 80WP) applied on onions, cabbages and tomatoes, two insecticides (Thiodan and Rocket EC) used on tomatoes and eggplant, insecticide + fungicide (Thiodan and Dithane M45) applied to onions, cabbage, eggplant and tomatoes. These farmers apply pesticides in mixtures. There were combinations of up to two pesticides in a single tank mix. Up to 90% had up to three pesticides in a mixture. Either farmers had no specific instructions from the label or extension staff regarding these tanks mixes.

f. Trend and reasons given for the trends in pesticide use: 62.5% of farmers who responded to the trend in pesticide use over the past 3 years said the trend was increasing, while 20.83% thought it was constant and 16.67% thought it was decreasing. The trend of pesticide use over the past 3 years in Bughore-Kabare region is on the rise as they farm in relatively similar environments and international organizations have started assisting them with agricultural inputs such as vegetable seeds. With the increase in the use of pesticides, there is also a decrease in bees observed by farmers in the environment of the study area. The reasons for increasing trends in pesticide use are ineffective pesticides, pest resistance, increasing insect damage, pest population, agricultural area, insect pests, plants and number of pests. The constant ones are that the pesticides are effective, same area, same farm size, correct instructions and effective pesticides, less pests, drought and even farm, same application everywhere and same pesticides used and the reasons for the tendency to the downside are heavy rains, unavailability of pesticides, price increase, less harvest, drought, good farm preparation and reduced agricultural area.

g. Perception of pesticide poisoning symptoms: Hundred percent of farmers reported feeling sick after routine application of chemical pesticides in the study area. However, the most common symptoms reported and included skin effects (37.5%), neurological system disorders (headache, dizziness) were (20.83%). Additionally, farmers reported suffering from sneezing (6.25%), excessive sweating (5.21%), coughing and poor vision (3.12%), nausea (2.08%) and stomach pain (1.04%). Therefore, skin effects, headaches and dizziness are dominant in the Bughore-Kabare region.

h. System of pesticide packaging management: Sixty-two point five percent of the farmers answered that the management system for pesticide containers is to leave them and keep them on the stakes and/or sticks in the field, while 20.83% buried them and 16.67% burned them. Pesticide packaging management system used by farmers is stake and/or stick in field in Bughore-Kabare area as they have no training in pesticide use, water pollution water, air, soil and living beings hence the problem of poisoning in the environment.

Discussion

The majority farmers were males in more farms of market

gardeners at the Bughore-Kabare area, eastern of DR. Congo. [27] and [28] reported that a small percentage of women (8% - 28%) are involved in market gardening in Togo too. The low involvement of women in the production of fruit vegetables (tomato, eggplant and pepper) could be explained in the fact of that, women are generally not empowered to apply the phytosanitary treatment required by these crops [20]. Indeed, the phytosanitary treatment is tedious (acquiring the product, preparing the solution and applying it using a sprayer), and complicated for the uninitiated who constitute a large proportion of peasant women. Our result joined the results of [27] and [29], the market gardeners farm carried on through no employment and/or no decent salary with a level of primary and secondary school. His reasons for choosing vegetable crops one of them for their short-cycle, easy-to-practice crops, another group for their short-term profitable investment and the last group for their crops with very high market value per unit area. This may be explained the important income generation and job creation [27,28] and in order to meet these challenges, poor families in cities resort to urban and peri-urban agriculture, in particular market gardening [27,28,30] reported similar result; the farmers assume that the only solution to pest problems is to spray more frequently and using different types of pesticides. However, [31] revealed that farmers were not receiving agricultural extension service hence have attempted various means especially in pesticides use when dealing with pest problems but were constrained by the lack of appropriate knowledge.

A lot of out of pesticides are unregistered for general use. [32] reported similar result in African countries and worrying risk values for the exposure of market gardeners to pirimicarb and Chlorpyrifos-methyl, thus reflecting a risk to the health of market gardeners. Given the large number of pesticides used and the frequency of application (very high risk of bioaccumulation of pesticides). It is important to note that chemical pesticides are toxic and their use cannot be accepted or encouraged unless the methods of use are perfectly mastered as well as the risks to human health and the natural environments likely to be affected [33,34]. WHO surveys have found that African countries import less than 10% of the pesticides used in the world, yet they account for half of accidental poisonings and more than 75% of fatal cases [35]. Although fungicides are not easily observed to cause serious and acute damage to farmer's health, they have been reported to cause some harm to farmer's skin and eyes [36]. It is also reported that there is a long-term risk for cancer development and endocrine disruption resulting from farmer's exposure to fungicides containing Mancozeb [36]. WHO Class Ib (highly hazardous) are not recorded in use. This pesticide can be fatal if inhaled, swallowed, or absorbed through the skin, even though the effects of contacts and/or inhalation may be delayed due to its formulation [37]. The effects of exposure even of a short duration can be delayed but there is a possibility of cumulative effects [38]. Usually amounts and types of pesticides used have been reported by [39] to show important differences among countries and among regions within one country depending on the type of agricultural production and level of economic development. More of farmers applied pesticide once a week. The fact that pesticides are more expensive and use some cultural control methods and occasionally botanical pesticides [40-42] reported that there is a need to bring to the attention of these farmers existing alternative pest management strategies that are cost effective and environmentally friendly. In Zimbabwe, although small-scale vegetable farmers use some cultural control methods and occasionally botanical pesticides, pest control is predominantly by the use of synthetic pesticides. Farmers did not have specific instructions either from the label or from extension staff regarding these tank mixtures. [43] in Benin, [44] in Tunisia and [45]in Birmania (Myanmar) reported the similar results. The tank mixture of pesticides observed in this study indicates that farmers lack basic knowledge of pesticides. [46] observed that there was an interaction between fungicides, insecticides and water mineral content that influenced the efficacy of individual pesticide against fungal pathogens and insect mortality and some tank mixtures induced phytotoxicity on tomato. There is limited information on the reaction and effects of the mixtures observed in this study. According [47], the total exposure to the chemical is the sum of exposure during pesticide storing, mixing, applying and disposing of the chemicals. As a result, and coupled with lack of basic knowledge of pesticides, farmers' decisions on what pesticides and how to use do not have a bearing on health or safety of the environment. The risk of long-term effects of the pesticides that were been used in the study area is high especially due to exposure to carcinogens, possible carcinogens and suspected endocrine disruptors. The pesticides were been mixed wrongly, mishandled and misused [39]. The farmers used more pesticides because they based the applications on calendar spray pesticides program without necessarily giving much priority to health and environmental considerations [48].

The trend of pesticide use over the past 3 years in Bughore-Kabare region is on the rise as they farm in relatively similar environments and international organizations have started assisting them with agricultural inputs such as vegetable seeds. With the increase in the use of pesticides, there is also a decrease in bees observed by farmers in the environment of the study area. In African countries, many government extension programs encourage the use of pesticides, but do not consider their effects in the environment and health risks [49]. This is a typical situation in many developing countries where the choice of pesticides to be used by farmers influenced by the suppliers [48]. The pesticide have a skin effects, headaches and dizziness, neurological system disorders (headache, dizziness), sneezing, excessive sweating, coughing and poor vision, nausea and stomach pain in the Bughore-Kabare region. The three routes of exposure to pesticides: dermal, respiratory and oral [50]. Usually, farmers assume that pesticides poisoning symptoms are normal so they get used to them [51]. Almost 750,000 people contract a chronic disease such as cancer each year because of exposure to pesticides, nerve damage, infertility and deformities, etc. In addition, although developing countries only employ 20% of all chemicals used in agriculture globally, they still account for more than 99% of deaths worldwide because of human poisoning pesticides [35]. The studies carried out in Indonesia [51] and in Ivory Coast [52] reported that pesticide applicators tended to accept a certain level of illness as an expected

and normal part of the work of farming and, do not report the symptoms in official health centres for formal medical assistance. These pesticides are inhaled through different routes via; oral (through the mouth and digestive system), dermal (through the skin), ocularly (through eyes) or by inhalation (through the nose and respiratory system). The pesticides have effect on the decline of biodiversity by indirect effect to the non-target organisms [53]. The pesticide packaging management system used by farmers is stake and/or stick in field in Bughore-Kabare area as they have no training in pesticide use, water pollution water, air, soil and living beings hence the problem of poisoning in the environment. Our result is similarly to [54]. The abandonment of packaging in the field poses a great danger to children and the uninitiated who may use it as second-use packaging and containers. Incineration of packaging (including pesticide waste and contaminated materials) is also not a good practice because during combustion, some pesticides produce highly toxic fumes which inhalation and / or contact are harmful to the human body and animals [54]. Likewise, the author points out that the burying of packaging (practiced by 6% of respondents in this study), residues and waste of pesticides presents the risk of contamination of groundwater. Pesticide packaging is generally abandoned in the field or incinerated as initially observed in other African countries [55,56]. According to [21], Nkolo area in west of DR Congo and its surroundings, the market garden fields being mainly installed along waterways for watering facilities, part of the packaging abandoned in the field ends up in the course of water carried by strong winds or runoff. The same is true for pesticides accumulated in the soil, which, after heavy rains, carried in the runoff to the rivers and volatile particles during the treatment, some of which are deposited directly in the rivers. At the end of the treatment, the market gardeners wash and wash their clothes in the streams. Contamination of waterways with pesticides is therefore not excluded in the study area, even though most market gardeners claim to maintain sprayers in the field so as not to pollute the waterways. Our result is in the same way to result of [57]. The result is in the same way with of the [21]. Good management use and proper disposal of agrochemicals is an important health and environmental issues in the developing countries [57,58] reported that, when pesticides are applied immediately before harvest, the level of pesticide residues on produce was greatly increased.

Conclusion

This study provides valuable information on the pesticides used, exposures, and perceptions on pesticide use, trends, and health symptoms by small-scale market gardeners' farmers. It can be used also to develop a tool to contribute to the reformation of pesticide policy in Bughore-Kabare area in eastern of DR. Congo. The training of all the stakeholders, from the whole saler to the retailers and farmers, appears to be one of the most effective methods to promote IPM. Emerging markets for organic and sustainably managed horticultural products should help to boost investment in IPM options and especially biological control. The Congolese government must create a quarantine, control and surveillance service for phytosanitary products, fruits and vegetables within the DRC country and at these borders.

Acknowledgments

The authors are thank-full to Marc De Meyer of Invertebrates Section at the Royal Museum for Central Africa for the many tips, for the ideas, proofreading and correction of this article as well as for the unfailing emotional support. Additionally, thankful to the participants especially farmers and pesticide retailers at Bugorhe area of the Kabare territory South Kivu province for sharing their time with us. We would also like express our gratitude to labs of Entomology Section at the Researcher Centre in Natural Sciences for providing research laboratory.

Conflicts of Interest

The authors declare that there was no conflict of interest. The authors are responsible for the content and writing of the paper.

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